15. African farmers have amazing allies in their cashew plantations

Jean-François Vayssières[(1, 2)]*, Florence Anato[(3)], Antonio Sinzogan[(3)], Appolinaire Adandonon[(4)], Rosine Wargui[(3)], Hermance Houngbo[(3)], Issa Ouagoussounon[(3)], Anaïs Chailleux[(5)], Pascal Danthu[(2)], Georg Goergen[(6)], Achille Adopo[(7)], Manuele Tamo[(6)], Joachim Offenberg[(8)]

(1) Campus agronomique de Kourou, CIRAD, Kourou-Pariacabo, 97310, France
(2) MUSE, Université de Montpellier - CIRAD, UPR HortSys, 34398 - Montpellier, France
(3) UAC, Université d'Abomey Calavi, FSA, 03BP 2819, Cotonou, Bénin
(4) ENSTA - Kétou, Université d'Agriculture de Kétou, BP 43, Kétou, Bénin
(5) MUSE - CIRAD, UPR HortSys, Biopass, ISRA-IRD, BP 1386, Dakar, Sénégal
(6) IITA, Biological Control Unit for Africa, 08 BP 0932, Cotonou, Bénin
(7) CNRA, 01 BP 1740 Abidjan 01, Côte d'Ivoire
(8) Université d'Aarhus, Vejlsoevej 25, 8600 Silkeborg, Danemark
*E-mail corresponding author: jean-francois.vayssieres@cirad.fr

Description. In West Africa, fruit trees are a crucial but often neglected component of people's lives and more than 50% of fruit crops are thought to be lost to insect pests every year. The relatively low adoption rate of old-IPM practices underpins the need to take up challenges and propose new pioneering control methods, such as using weaver ants in cashew plantations.
Literature. The genus *Oecophylla* is represented by two tropical species, *Oecophylla longinoda* (Latreille) and *Oecophylla smaragdina* (Fabricius), occurring in sub-Saharan Africa and Australasia, respectively. In southern China, but also in Vietnam, weaver ant husbandry is a centuries-old tradition. Positive ant-managing experiences from Asia have generated some recent interest in Africa. In sub-Saharan Africa, cashew production is severely constrained by infestations of several insect pests. Sap-sucking bugs, leaf miners and trunk-branch borers are pests that adversely affect yields (total losses of up to 80%) and the quality of harvestable nuts. Recent studies have highlighted the positive role of weaver ants against these insect pests in cashew plantations of Benin, Ghana and Tanzania. Finally, *O. longinoda* provided four comparative advantages for cashew production i) better yields, ii) larger nuts, iii) higher proportions of marketable kernel mass and iv) a potential fertilization effect.
Conclusions. The "weaver ant technology" could be more widely used in sub-Saharan Africa because it is i) effective, ii) low-cost, iii) labour-saving, iv) self-regenerating. It is thus particularly suitable for low-resource smallholder farmers in sub-Saharan cashew plantations and also for mango, citrus, guava plantations.

Les planteurs africains ont des alliées étonnants dans leurs plantations d'anacardiers
Description. En Afrique de l'Ouest, les fruitiers constituent une composante cruciale pour le développement des populations rurales mais une composante souvent sous-valorisée avec plus de 50 % de pertes dues aux insectes. Le taux d'adoption relativement faible des anciennes méthodes de lutte intégrée pourrait être un argument supplémentaire pour faire face aux défis et proposer de nouvelles méthodes de lutte novatrices comme la gestion des fourmis oecophylles dans les plantations d'anacardiers.
Littérature. Le genre *Oecophylla* est représenté par deux espèces tropicales *Oecophylla longinoda* (Latreille) et *Oecophylla smaragdina* (Fabricius), d'Afrique sub-Saharienne and d'Australasie, respectivement. Dans le sud de la Chine mais aussi au Vietnam l'élevage des oecophylles est une très vieille tradition (pluri-centenaire). Les expériences asiatiques positives d'utilisation des oecophylles ont éveillé l'intérêt du secteur rural Africain. En Afrique sub-Saharienne, la production d'anacarde est sévèrement pénalisée par les infestations de plusieurs types de ravageurs dont les punaises piqueuses des fruits, les mineuses des feuilles, les foreurs de troncs et branches, ravageurs qui affectent négativement les rendements (pertes globales jusqu'à 80 %) et la qualité des noix. Des études récentes ont mis en évidence qu'*O. longinoda* était un agent de contrôle biologique efficace contre ces ravageurs au Bénin, au Ghana et en Tanzanie. Au final, *O. longinoda* fournit quatre avantages comparatifs aux producteurs d'anacardes à savoir i) l'augmentation des rendements, ii) une taille plus importante des noix, iii) une proportion plus importante des amandes commercialisables, et iv) une amélioration potentielle de la fertilisation.

Conclusions. La «technologie des fourmis oecophylles» pourrait être mieux valorisée en Afrique car elle est i) effective, ii) efficiente, iii) elle économise le travail du planteur, iv) elle s'auto-entretient. Elle est donc particulièrement adaptée aux plantations d'anacardiers comme à d'autres cultures fruitières (manguiers, agrumes, goyaviers) d'Afrique subsaharienne.

1. SIGNIFICANCE OF THIS STUDY

What is already known on this subject?

– There is a very ancient interest in using Asian weaver ants in Southeast Asia.
– A relatively recent interest in using African weaver ants has emerged in sub-Saharan Africa, especially in West Africa.

What are the new findings?

– In West Africa, several insect pests of economic significance were significantly controlled by weaver ants in cashew plantations.
– Both cashew yields and quality of the nuts were significantly improved in cashew plantations harboring weaver ants.

What is the expected impact on horticulture?

This review provides useful information that could be used by growers in pest management targeting cashew bio-agressors with weaver ants.

2. INTRODUCTION

The cashew tree, *Anacardium occidentale* L. (Sapindales: Anacardiaceae) is an important crop for West African growers, mainly because of strong international demand. It originates from South America (Brazil) and was introduced into Benin in the sixteenth century by Europeans (McLaughlin et al., 2008), spreading widely thereafter throughout the agro-ecological zones of the country. It was planted in West Africa as it could mainly serve as i) a cash crop (Monteiro et al., 2017), ii) a way of controlling desertification (Soro et al., 2011), iii) a sign of land occupancy in association with mango trees (Vayssières et al., 2008), and iv) because it had proven hardiness. Above all, West African growers attribute particular importance to the nuts, but also to the apples and shells for those also involved in processing. Cashew is an important value chain in West Africa and, in economic terms, it is a highly profitable cash crop for a number of African countries.

Over the 2010-2014 period, the African continent supplied almost 50% of world cashew nut production (FAO, 2017). These statistics highlight the major effort made over the last decade by the producing countries of sub-Saharan Africa (Nigeria, Ivory Coast, Benin, Guinea Bissau, Guinea, Burkina, Mozambique, Tanzania, etc.) to increase their production. International demand for the West African cashew nut lies in its particular flavour appreciated by consumers, and the absence of pesticide treatments, as in Benin (Tanjiékpon et al., 2010).

Unfortunately, the vegetative organs and fruits of the cashew tree are severely affected by many insect pests (Dwomoh et al., 2009; Agboton et al., 2014; Anato et al., 2015). These Hemiptera, Coleoptera and Lepidoptera pests belong to the families Miridae (damage to the annual flush), Coreidae-Alydidae (damage to nuts and apples), Bostrichidae (damage to branches and trunks), and Thripidae and Gracillariidae (damage to leaves); they cause cashew nut losses each year in West Africa, seriously penalizing the growers involved.

Outside China, the effectiveness of weaver ants as natural control agents in protecting cashew trees has been shown in Australia (Peng at al., 1995; Peng et al., 1997a), Vietnam (Peng et al., 2014) and very recently in some African countries. These last data are relatively new. A map of the world (Figure 1) indicates the main cashew nut producing zones and the potential for their protection using the two species of weaver ants.

To date, the cashew supply chain in West Africa has remained of the Organic Farming type, or in certain zones a sector with very few pesticide applications. This opportunity may enable better use to be made of the potential offered by biological control agents. This involves weaver ants, or *Oecophylla* ants, which are of great interest for protecting West African fruit crops using the African weaver ant (*Oecophylla longinoda* (Latreille)).

This documentary research was aided by the fact that we have been working on this subject for around ten years in West Africa, focusing on fruit fly control with African weaver ants (Vayssières et al., 2016).

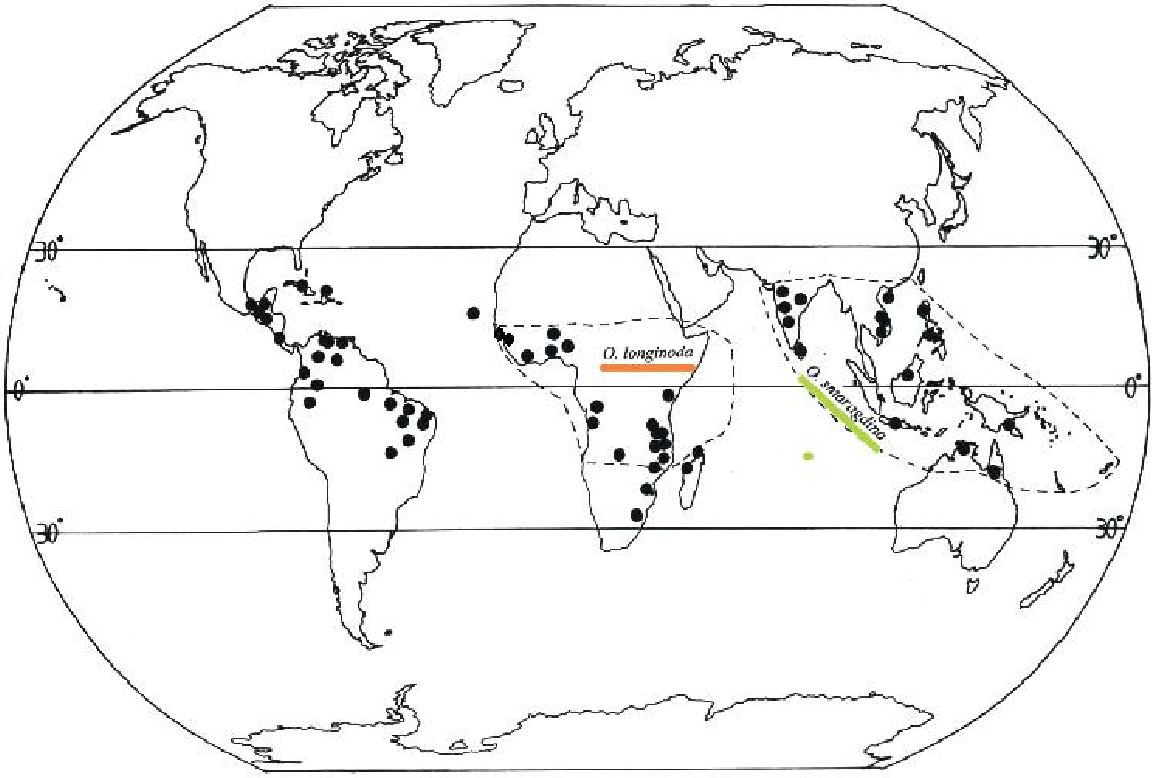

Figure 1. Distribution of two weaver ant species, *O. longinoda* and *O. smaragdina*, depending on world cashew production zones (•) (update of a map by R. Peng) – *Distribution des deux espèces d'œcophylles,* O. longinoda *et* O. smaragdina*, en fonction des zones mondiales de production d'anacardier (•).*

3. LITERATURE

Weaver ants are dominant as predators of many arthropods in terrestrial and arboreal ecosystems of tropical and sub-tropical zones (Hölldobler & Wilson, 1990). The members of a colony constantly interact and work together in their own territory by way of different types of pheromones. Like most ant species, weaver ants live in a society, in trees including fruit trees (Figures 2a, b, c, d), inside nests made of leaves woven together by their larvae. The members of a colony (tens of thousands of individuals) live in several nests built in several trees.

They chase off other invertebrates from their trees, but also over an area of several hundred m^2 below their canopies. Weaver ants are generalist predators that feed especially on insects, particularly crop pests such as tephritid larvae (Figure 3) or cashew bugs (Figure 4). For a colony of twelve nests, Dejean (1991) estimated that weaver ants brought back 45,000 prey per year in Cameroon.

It is even more interesting that the predation practised by weaver ants on other invertebrates is the repellent effect against pests that they generate in fruit crops (Adandonon et al., 2009; Van Mele et al., 2009a). Among the complex signals emitted by weaver ants, it would particularly seem to be their semiochemical signals that play a major role in protecting tropical fruit crops.

Weaver ants are especially fond of biotopes with abundant rainfall and a luxuriant perennial vegetation. Trees with broad, supple leaves, or trees with small but abundant leaves, are preferred for building their silken nests.

Traditional use of weaver ants (*O. smaragdina*) in Asia. The Asian weaver ant, *O. smaragdina*, also called "living insecticide", is the most ancient example of biological control in the world, in Southeast Asia (Groff & Howard 1924; Hölldobler & Wilson, 1990). Two thousand years ago, the Asian weaver ant was already being used in southern China to control Citrus pests (Chen, 1962; Yang, 1982; Huang & Yang, 1987). Its use was abandoned in the 1960s when synthetic insecticides came onto the market in Southeast Asia.

However, this beneficial insect acquired its credentials later in Australia than in China or Vietnam. In Australian cashew orchards, the University of Darwin demonstrated that *O. smaragdina* effectively controlled some major pests, such as the bugs *Helopeltis pernicialis* Stonedahl Malipatil & Houston, *Amblypelta lutescens* Distant, as well as the moth *Anigraea ochrobasis* (Hampson) (Peng et al., 1997b; Peng & Christian, 2005).

Figure 2. *O. longinoda* nests on a) mango (Anacardiaceae), b) pomelo (Rutaceae), c) cashew (Anacardiaceae), d) guava (Myrtaceae) (Jean-François Vayssières, credit) – *Nids d'*O. longinoda *sur a) manguier, b) pomelo, c) anacardier, d) goyavier*.

Figure 3. Capture of mango fruit fly larvae (Diptera: Tephritidae) on a mango cv Eldon in the department of Borgou – Benin (Jean-François Vayssières, credit) – *Capture de larves de Tephritidae sur une mangue cv Eldon dans le département du Borgou-Bénin*.

Figure 4. Capture of *Pseudotheraptus devastans* (Hemiptera: Coreidae) on cashew inflorescences in the department of Borgou – Benin (Jean-François Vayssières, credit) – *Capture de* Pseudotheraptus devastans *(Hem. : Coreidae) sur des inflorescences d'anacardier dans le département du Borgou-Bénin*.

Relatively recent interest in using weaver ants (*O. longinoda*) in sub-Saharan Africa. In sub-Saharan Africa, studies on *O. longinoda* effectiveness against pests have existed for several decades, but on fruit trees other than cashew. In Ghana, Room (1971) and Majer (1972) showed that *O. longinoda* significantly reduced damage by *Distantiella theobroma* (Distant) in cacao trees. In Tanzania, Way (1951) and Vanderplank (1960) also highlighted the efficiency of *O. longinoda* against *Pseudotheraptus wayi* Brown in coconut palms. Some studies undertaken in Ghana showed that the presence of *O. longinoda* reduced the incidence of two major cacao diseases transmitted by mirid bugs captured by weaver ants (Leston, 1973).

More recently, some studies have shown the very important role played by *O. longinoda* in fruit tree plantations as a biological control agent against various pests in Ghana, Tanzania, Senegal and Benin (Van Mele et al., 2007; Ativor et al., 2012; Olutu et al., 2013; Diamé et al., 2015; Anato et al., 2015).

Let us consider cashew:

In Ghana, Dwomoh et al. (2008) and Aidoo (2009) showed the fundamental role played by *O. longinoda* in controlling cashew bugs. The bugs targeted by *O. longinoda* were *Anoplocnemis curvipes* (Fabricius), *Helopeltis schoutedeni* Reuter, and *Pseudotheraptus devastans* (Distant).

In Tanzania, Oluthu et al. (2013) and Abdullah et al. (2016) showed the fundamental role played by *O. longinoda* in controlling cashew bugs. The bugs targeted by *O. longinoda* were *Helopeltis* spp. and *Pseudotheraptus wayi* Brown.

In Benin, studies repeated over two years showed that 3 treatments of cashew trees with weaver ants produced 78%, 122% and 151% more nuts than the control cashew trees, i.e. without weaver ants (Anato et al., 2015). In addition, the quality of the nuts produced on the cashew trees with weaver ants was better than on the control trees, and their average size was larger (Anato et al., 2015; Anato et al., 2017). The cashew bugs targeted by *O. longinoda* were *A. curvipes*, *H. schoutedeni*, *Mirperus jaculus* (Thnb.), *P. devastans*, and *Tupalus fasciatus* (Dallas).

Other advantages. Apart from insects (Vayssières et al., 2015), weaver ants attack and/or put off other types of pests, such as rats, snakes, fruit bats and…. thieves, as reported in Guinea (Van Mele et al., 2009b) and Benin. Indeed, some Beninese planters from Borgou have introduced these splendid weaver ants into their orchards to protect their fruits from unscrupulous people.

The consequences for fruit quality and yields are substantial. According to some women harvesters (in Guinea and Benin), fruits from trees with weaver ants keep better and are sweeter. For instance, mangoes picked from trees with weaver ant nests are of better quality, as was shown in Cotonou by Houngbo (2011), who launched a PhD thesis on this subject. Along the same lines, Asian producers have found the fruits of Citrus trees harbouring weaver ants to be juicier, sweeter and glossier.

Another expected advantage of weaver ants in cashew trees concerns the fertilization of trees harbouring weaver ant nests. It was recently shown that host trees could recover nitrogen via their leaves from the faeces of weaver ants, thereby increasing their leaf nitrogen content (Vidkjaer et al., 2015; Pinkalski et al., 2015). Some studies have revealed important nutrient flows (nitrogen, carbon, etc.) between weaver ants and their host plants, as a fundamental component of ant-plant mutualism (Pinkalski et al., 2016).

Economic costs. In Australia, results from field experiments (1998-1999) showed that the cost of chemical insecticide treatments was 515 A$/ha/year (excluding labour, machinery and fuel costs), while the cost of introducing and managing weaver ants was 360 A$/ha/year (including the cost of labour, various materials and local transportation of colonies). The saving was therefore 155 A$/ha/year (Peng et al., 2004).

To be complete, it needs to be added that once colonies had been introduced into cashew plantations, they remained there for several years running, meaning that the cost of introducing and managing weaver ants was much cheaper than annual chemical insecticide treatments. Taking yields into account, orchards protected by weaver ants earned profits of a little over 1,000 A$/ha/year, compared to orchards protected by chemical pesticides (Peng et al., 2004).

The cost-benefit ratio, like other financial indicators, was positive in plots with weaver ants in Tanzania (William et al., 2015).

4. CONCLUSIONS

Using weaver ants as a biological control agent is taking on increasing importance in sub-Saharan Africa and may thus bring an Organic Farming label for cashew crops (Abdullah et al., 2016), as for mangoes or Citrus fruits (Van Mele & Vayssières, 2007a). One of our main aims is to provide all stakeholders in the fruit supply chains, at different levels, with practical information on using weaver ants to control cashew pests.

Managing and using weaver ant colonies is a means of action that is well suited to the sustainable development of perennial fruit systems (cashew, but also mango and Citrus, etc.) in sub-Saharan Africa, thanks to their effectiveness, constant availability, and their wide distribution (Van Mele & Vayssières, 2007b; William et al., 2015). In fact, they are biological control agents that are as efficient as they are effective. In addition, it is not inconceivable to imagine the potential rearing of queens and workers of this African species for food purposes, as has been the case for several decades in Asia (Offenberg & Wiwatwitaya, 2010).

Using weaver ants offers many comparative advantages: i) very low cost, ii) enables labour savings in plantations, iii) self-maintaining, iv) requires very little intervention and v) its efficiency is crucial. These conservation biological control advantages have been developed over the last decade in Benin, as well as in Ghana and Tanzania, through different R4D projects funded by EU-WTO, WAEMU and DANIDA.

Acknowledgements

We thank the West African Fruit Fly Initiative (WAFFI) staff of Benin and Peter Biggins for translation. Thanks are also due to donors EU-WTO, WAEMU, DANIDA and institutions of IITA and CIRAD.

Bibliography

Abdullah N.R. et al., 2016. Potential of *Oecophylla longinoda* Latreille (Hymenoptera: Formicidae) in managing major insect pests in organic cashew production systems. *Organic Agriculture*, **7**, 95-104.

Adandonon A. et al., 2009. Density of pheromone sources of the weaver ant *Oecophylla longinoda* (Hymenoptera: Formicidae) affects oviposition behaviour and damage by mango fruit flies (Diptera: Tephritidae). *International Journal of Pest Management*, **55**, 85-292.

Agboton C. et al., 2014. Insect fauna associated with *Anacardium occidentale* (Sapindales: Anacardiaceae) in Benin, West Africa. *Journal of Insect Science*, **14**, DOI: 10.1093/jisesa/ieu091.

Aidoo K.S., 2009. Boosting cashew production in Ghana. *Bees for Development – Information Portal Article*. http://www.beesfordevelopment.org/portal/print.php?id=1819[18-02-2013 15:20:19].

Anato F. et al., 2015. Reducing losses inflicted by insect pests on cashew, using weaver ants as efficient biological control agent. *Agricultural and Forest Entomology,* **17**, 285-291.

Anato F. et al., 2017. *Oecophylla longinoda* (Hymenoptera: Formicidae) lead to increased cashew kernel size and kernel quality. *Journal of Economie Entomology*, doi: 10.1093/jee/tox054

Ativor I.N., Afreh-Nuamah K., Billah M. & Obeng-Ofori D., 2012. Weaver Ant *Oecophylla longinoda* (Latreille) (Hymenoptera: Formicidae) activity reduces fruit fly damage in citrus orchards. *Journal of Agricultural Science and Technology,* **A2**, 449-458.

Chen S., 1962. The oldest practice of biological control: the culture and efficacy of *Oecophylla smaragdina* Fabr. in orange orchards. *Acta Entomologica Sinica,* **11**, 401-407.

Dejean A., 1991. Adaptation d'*Oecophylla longinoda* (Formicidae-Formicinae) aux variations spatio-temporelles de proies. *Entomophaga,* **36**, 29-54.

Diamé L. et al., 2015. Influence of *Oecophylla longinoda* Latreille (Hymenoptera: Formicidae) on mango infestation by *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) in relation to Senegalese orchard design and management practices. *African Entomology,* **23**, 294-305.

Dwomoh E.A. et al., 2009. Investigations on *Oecophylla longinoda* Latreille (Hymenoptera: Formicidae) as a biocontrol agent in the protection of cashew plantations. Pest Management Science, **65**, 41-46.

FAO - Food and Agricultural Organization. 2017. Country-wise production of cashew nuts in 2010-2014. (http://faostat.fao.org) (accessed 11 July 2017).

Groff W.G. & Howard C.W., 1924. The cultured citrus ant of South China. *Lingnan Agricultural Review*, **2**, 108-114.

Hölldobler B. & Wilson E.O., 1990. *The ants*. Harvard University Press, Cambridge, Ma, USA, 732 p.

Huang H.T. & Yang P., 1987. The ancient cultural citrus ant, a tropical ant, is used to control insect pests in southern China. *Bioscience*, **37**, 665-671.

Houngbo H., 2011. *Évaluation de la qualité nutritionnelle, microbiologique et organoleptique de la mangue (*Mangifera indica*) protégée par les fourmis rouges* (Oecophylla longinoda). Mémoire du Master en Normes, Contrôle de Qualité et Technologie Alimentaire. U.A.C. Cotonou. 64 p.

Leston D., 1973. The ant mosaic, tropical tree crops and the limiting of pests and diseases. *Ans*, **19**(3), 311-341.

Majer J.D., 1972. The ant-mosaic in Ghana cocoa farms. *Bulletin of Entomological Research*, **62**, 151-160.

McLaughlin J., Balerdi C. & Jonathan C., 2008. *Cashew-apple fruit growing in the Florida home landscape*. Document HS1127; Series of the Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Monteiro F. et al., 2017. Cashew as a high agricultural commodity in West Africa: insights towards sustainable production in Guinea-Bissau. *Sustainability*, **9**, 1666, http://dx.doi.org/10.3390/su9091666

Offenberg J. & Wiwatwitaya D., 2010. Sustainable weaver ant (*Oecophylla smaragdina*) farming: harvest yields and effects on worker ant density. *Asian Myrmecology*, **3**, 55-62.

Olotu M.I. et al., 2013. Efficacy of the African weaver ant *Oecophylla longinoda* (Hymenoptera: Formicidae) in the control of *Helopeltis* spp. (Hemiptera: Miridae) and *Pseudotheraptus wayi* (Hemiptera: Coreidae) in cashew crop in Tanzania. *Pest Management Science*, **69**, 911-918.

Peng R., Christian K. & Gibb K., 1995. The effect of the green ant, *Oecophylla smaragdina* (Hymenoptera Formicidae), on insect pests of cashew trees in Australia. *Bulletin of Entomological Research*, **85**, 279-284.

Peng R., Christian K. & Gibb K., 1997a. Control threshold analysis for the tea mosquito bug, *Helopeltis pernicialis* (Hemiptera Miridae) and preliminary results concerning the efficiency of control by the green ant, *Oecophylla smaragdina* (F.) (Hymenoptera: Formicidae), in northern Australia. *International Journal of Pest Management*, **43**, 233-237.

Peng R., Christian K. & Gibb K., 1997b. Distribution of the green ant, *Oecophylla smaragdina* (F.) (Hymenoptera: Formicidae), in relative to native vegetation and the insect pests in cashew plantations in Australia. *International Journal of Pest Management*, **43**, 203-211.

Peng R., Christian K. & Gibb K., 2004. *Implementing ant technology in commercial cashew plantations and continuation* *of transplanted green ant colony monitoring*. A report for the Rural Industries Research and Development Corporation. RIRDC Project No UNT-5A, 42 p.

Peng R., Christian K. & Gibb K., 2005. Ecology of the fruit spotting bug, *Amblypelta lutescens lutescens* Distant (Hemiptera: Coreidae) in cashew plantations, with particular reference to the potential for its biological control. *Australian Journal of Entomology*, 44, 45-51.

Peng R., Lan L.P. & Christian K., 2014. Weaver ant role in cashew orchards in Vietnam. *Journal of Economic Entomology*, **107**, 1330-1338.

Pinkalski C. et al., 2015. Quantification of ant manure deposition in a tropical agroecosystem: implications for host plant nitrogen acquisition. *Ecosystems*, **18**, 1373-1382.

Pinkalski C. et al., 2016. Macronutrient exchange between the Asian weaver ant *Oecophylla smaragdina* and their host plant. *Ecosystems*, **19**, 1418-1428.

Room P.M., 1971. The relative distributions of ant species in Ghana's cocoa farms. *Journal of Animal Ecology*, **40**, 735-741.

Soro D. et al., 2011. The cashew (*Anacardium occidentale*) industry in Côte d'Ivoire: analysis and prospects for development. *Fruits*, **66**, 237-245.

Tanjiékpon A.M., 2010. *Analysis of the Benin cashew sector value chain*. African cashew initiative (ACi), GTZ International Fondation, Eschborn, Germany, 32 p.

Vanderplank F.L., 1960. The bionomics and ecology of the red ant tree, *Oecophylla* sp., and its relationship to the coconut bug *Pseudotheraptus wayi* Brown (Coreidae). *Journal of Animal Ecology*, **29**, 15-33.

Van Mele P. et al., 2007. Effects of an African weaver ant, *Oecophylla longinoda*, in controlling mango fruit flies (Diptera Tephritidae) in Benin. *Journal of Economic Entomology*, **100**, 695-701.

Van Mele P. et al., 2009a. Ant cues affect the oviposition behaviour of fruit flies (Diptera Tephritidae) in Africa. P*hysiological Entomology*, **34**, 256-261.

Van Mele P., Camara K. & Vayssières J.-F., 2009b. Thieves, bats and fruit flies: local ecological knowledge on the weaver ant *Oecophylla longinoda* in relation to three 'invisible' intruders in orchards in Guinea. *International Journal of Pest Management*, **55**, 57-61.

Van Mele P. & Vayssières J.-F., 2007a. Weaver ants help farmers to capture organic markets. *Alternatives Pesticides News*, **75**, 9-11.

Van Mele P. & Vayssières J.-F., 2007b. West Africa's mango farmers have allies in the trees. *Biocontrol News and Information*, **28**, 56-58.

Vayssières J.-F. et al., 2008. The mango tree in northern and central Benin: cultivar inventory, yield assessment, early infested stages of mangoes and economic loss due to the fruit fly (Diptera Tephritidae). *Fruits*, **63**(6), 335-348.

Vayssières J.-F. et al., 2015. Seasonal pattern in food gathering of the weaver ant *Oecophylla longinoda* (Hymenoptera: Formicidae) in mango orchards in Benin. *Biocontrol Science and Technology*, **25**, 1359-1387.

Vayssières J.-F. et al., 2016. The use of weaver ants in the management of fruit flies in Africa. *In*: Ekesi S., Mohamed S. & de Meyer M. (eds). *Fruit Fly Research and Development in Africa, Towards a Sustainable Management Strategy to Improve Horticulture*. Springer, p. 389-434.

Vidkjær N.H. et al., 2015. Are ant feces nutrients for plants? A metabolomics approach to elucidate the nutritional effects on plants hosting weaver ants. *Metabolomics*, **11**, 1013-1028.

Way M.J., 1951. An insect pest of coconuts and its relationship to certain ant species. *Nature*, **168**, 302.

William J.G. et al., 2015. Benefit-cost analysis of alternative insect pest management in cashew and mango orchards. *Quarterly Journal of Econometrics Research*, **1**, 32-44.

Yang P., 1982. Biology of the yellow citrus ant, *Oecophylla smaragdina*, and its utilization against insect pests. Acta Scientiarum *Naturalium Universitatis Sunyatseni*, **3**, 102-105.